SEQUENCE OF WINTERS IN THE NORTHEASTERN UNITED STATES.[1]

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SYNOPSIS.

A study of the sequence of mean winter temperatures since 1812 in the northeastern United States shows apparently no other than a chance relationship four-fifths of the time. The other fifth includes two remarkable series of alternating cold and warm winters, with almost identical preliminaries of a few moderately mild winters, an ordinary or moderately-cold winter, and then a severe winter, which which opens the alternating series—severe, warm, severe, warm, etc. The opening severe winters in these two series were those of 1872–73 and 1917–18. Thus we examine with interest the records of the winters of 1876–77, 1877–78 ....., 1882–83 and wonder whether the winters of 1921–22, 1922–23 ...., 1927–28 will alternate cold, warm, cold, etc., a those of 45 years ago did for such a long period. A study of the weather maps of these winters of the seventies and eighties in conjunction with those of the past few years and of the present might show not only the immediate cause of these alternating winters, but also might give us a hint as to when to expect our present series of alternations to cease.

INTRODUCTION.

The sequence of seasons has long been known to be not a chance one. Weather types tend to persist rather than to change. European [2] and American [3] investigators seem to have established the fact that a season appreciably above or below normal in temperature is likely to be followed by one to three or more seasons having temperature departures in the same direction. Thus it *may* be that "forecasters" of mild or of cold winters who rely upon some biological signs [4] in autumn may justly claim more than chance success, though for reasons different from those commonly advanced. Five out of the seven winter predictions which came to me last fall from newspapers east of the Mississippi River were to the effect that this winter would be mild, according to indications afforded by birds, worms, squirrels, muskrats, frogs, etc. It should pay meteorologists to compare further [5] the types of tracks of HIGHS and LOWS in autumns preceding cold winters with those preceding mild winters and to correlate departures of temperature, or other weather elements, in September, October, and November with the character of the following winter months, at many places. [6]

IS THE SEQUENCE OF WINTERS A CHANCE ONE?

Perhaps we can get some indication of the character of a coming winter from that of the preceding one. In the last 50 years' record [7] throughout the northeastern quarter of the United States, the winters alternated warmer-colder-warmer, etc., in four-fifths of the cases, whereas by chance such alternations should have occurred in only two-thirds of the cases.[8] The most important single group of alternations involved the 12 consecutive winters from 1871 to 1883. At Washington, D. C., New York, N. Y., and Cincinnati, Ohio, minor alternations lasted till 1886, and at Chicago till 1887. (See fig. 1.) Such a sequence of alternating colder and warmer winters was evidently the result of an oscillatory movement of the North Atlantic and North American "grand centers of action of the atmosphere."[9] When large changes between the characters of successive winters occur on one side of the Atlantic, large ones are usually occurring on the other side as well. Places even as far separated as Paris and Washington show this connection, at least so far as the period with 40 winters, 1872–1912, is concerned.[10]

Mainly as a result of this long period of alternating winters, so much above and below the average, a count of the unusually cold winters (i. e., those having mean temperatures more than 3° F. below the average), for example, in the 50-year record at Washington, shows that a winter with a marked departure (3° F. or more) from the average was usually followed by an opposite departure of marked degree the next winter. Following each of 6 out of the 7 cold winters (more than 3° F. below the average) the next winter was at least 1.5° above the average, and half were more than 3.5° above the average. Each of the winters following immediately after 7 of the 9 winters more than 3° F. above the average was at least 1.1° below the average, and 3 were more than 3° below the average. An examination of the New York City temperature data gives much the same results.[11] Last winter having been cold, it appeared that the chances were 6 to 1 that this one, 1920–21, would be warm.[12]

There being some smaller as well as larger alternations in the mean winter temperatures, it seemed desirable to make dot charts showing the sequence of winter to winter and of a first winter to the second one after. As was to be expected, the lines of best fit on these charts indicated a warm winter to follow a cold one, a normal winter to follow a normal one, a cold winter to follow a warm one, and any winter to be like the second one preceding. Values for each winter obtained from the averaged indications of the two dot charts for Washington, D. C., came within 2° F. of the actual winter means

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[1] Past presented in more detail before American Meteorological Society at Chicago, Ill., Dec. 28, 1920.

[2] See Hann, J. von, Lehrbuch der Meteorologie, 3d ed., Leipzig, 1915, pp. 629, 630, 631, 632–637.

[3] Fassig, Oliver L., Climate and weather of Baltimore, Maryland Weather Service, 1907, pp. 103–104.

Cox, H. J., and Armington, J. H., The weather and climate of Chicago, Geogr. Soc of Chicago, 1914, pp. 23–24.

[4] See Animal weather prophets, MO. WEATHER REV., February, 1920, 48:98; and Weather by rule of thumb, *Bull. Am. Metl. Soc.*, April, 1920, 1:39.

[5] Such an investigation by Mr. E. H. Bowie, supervising forecaster, Washington, D. C. is in progress.

[6] Mr. J. H. Scarr's discovery that open winters followed 9 out of the 12 unusually mild Octobers in the past 50 years at New York City should be encouraging for further work.

[7] In this study the mean temperatures of December, January, and February were added together and divided by 3. The resulting "mean winter temperatures" may be objected to on several grounds: (1) The temperature of each day in February has a weight 10 per cent greater than that of each day in January and December; (2) one extremely cold month, which would give character to the winter as a "severe" one, might have its large minus departure in temperature nearly or entirely obliterated by plus departures in the other two months; and (3) winter weather in November, March, and even other months does not show. Objection (1) could be answered only with considerable labor. The refined means would in any event not differ greatly from those used. Objection (2) could be answered more or less satisfactorily by substituting either (*a*) the number of days with maximum temperature freezing or below, or (*b*) the day-degrees of temperature below freezing. (Cf. Angot, Alfred, On a method for classifying winters, MO. WEATHER REV., November, 1914, 42: 625.) A curve of (*a*) was made for Washington, and the values of (*b*) have been published. (Abbe, Cleveland, jr., Washington and Paris winters, ibid., pp. 626–628.) On comparison with the curve of mean winter temperatures no essential differences in the general forms of the three were in evidence. Objection (3) is not important. A comparison of curves (*a*) showing days with maximum temperature freezing or below for December to February, inclusive, and for October to April, inclusive, indicated that little was likely to be gained from the addition of other months to December, January, and February. The answers to objections (2) and (3) are based on data for Washington, D. C., only, and thus may not hold for more northerly stations, where winters are longer. (See also, Winter types on the basis of five-day temperature means, and On mild winters, ibid., February, 1920, 48: 102.)

[8] Besson, L., On the comparison of meteorological data with results of chance, ibid., 89–94.

[9] See Gregory, J. W., Meteorological influences of the sun and the Atlantic, MO. WEATHER REV., August, 1920, 48: 465–466 (repr. from *Nature* (London), Aug. 5, 1920, pp. 715–716); Stupart, R. F., The variability of corresponding seasons in different years, abstr. in MO. WEATHER REV., February, 1920, 48: 101; Brooks, C. F., Ocean temperatures in long-range forecasting, ibid., November, 1918, 46: 510–512; and Humphreys, W. J., Why some winters are warm and others cold in the eastern United States, ibid., December, 1914, 42: 672–675, 35 charts.

[10] The findings here mentioned were computed by C. F. B. from data given in Table 2, p. 627, Cleveland Abbe, jr., loc. cit.

[11] Cf. curve of winter temperatures and discussion by J. Malcolm Bird, in *Sci. Amer.*, Mar. 6, 1920, pp. 253, 261, 262, and further discussion by C. F. Brooks, MO. WEATHER REV., February, 1920, 48: 101, *102*.

[12] See MO. WEATHER REV., ibid., p. 102, and *Bull. Am. Metl. Soc.*, May, 1920, 1: 49.

in 67 per cent of the cases, whereas the winter means were within 2° F. of the average in only 42 per cent of the cases.

An interesting circumstance in connection with the use of these dot charts was that the indications from the Washington, D. C., "forecasting" lines of best fit gave better "forecasts" of mean winter temperatures at New Bedford, Mass., New York, N. Y., and even Chicago, Ill., than did the best dot charts prepared from the observations made at these places themselves. The reason for this seems to be that Washington temperatures better indicate the general conditions controlling the winters of the northeastern United States than do the temperatures at other places, at which the local effects of snow-cover, lake or ocean influence may occasionally obscure general tendencies in the temperature.

those outside the group comprising the less extreme half of the winters), seem to be just what would be expected by chance. Two evidences of a connected sequence, however, are not blotted out: (1) Following unusually cold winters (3° F. or more below the average) the chances are 10 to 4 at New Bedford, Mass. (record 1812–1920), that the next winter will be above the average in mean temperature. This percentage, 71, is decidely higher than the percentage, 47, of winters above the average. The corresponding percentages for the Baltimore (adjusted) record (1817–1920), in which there were 12 cold winters, are 67 and 45. Following unusually warm winters the chances for a cold winter are only 9 to 7 at New Bedford and 11 to 9 at Baltimore. (2) It does not seem likely that chance could produce an unbroken series of 12 to 16 alternating colder and warmer

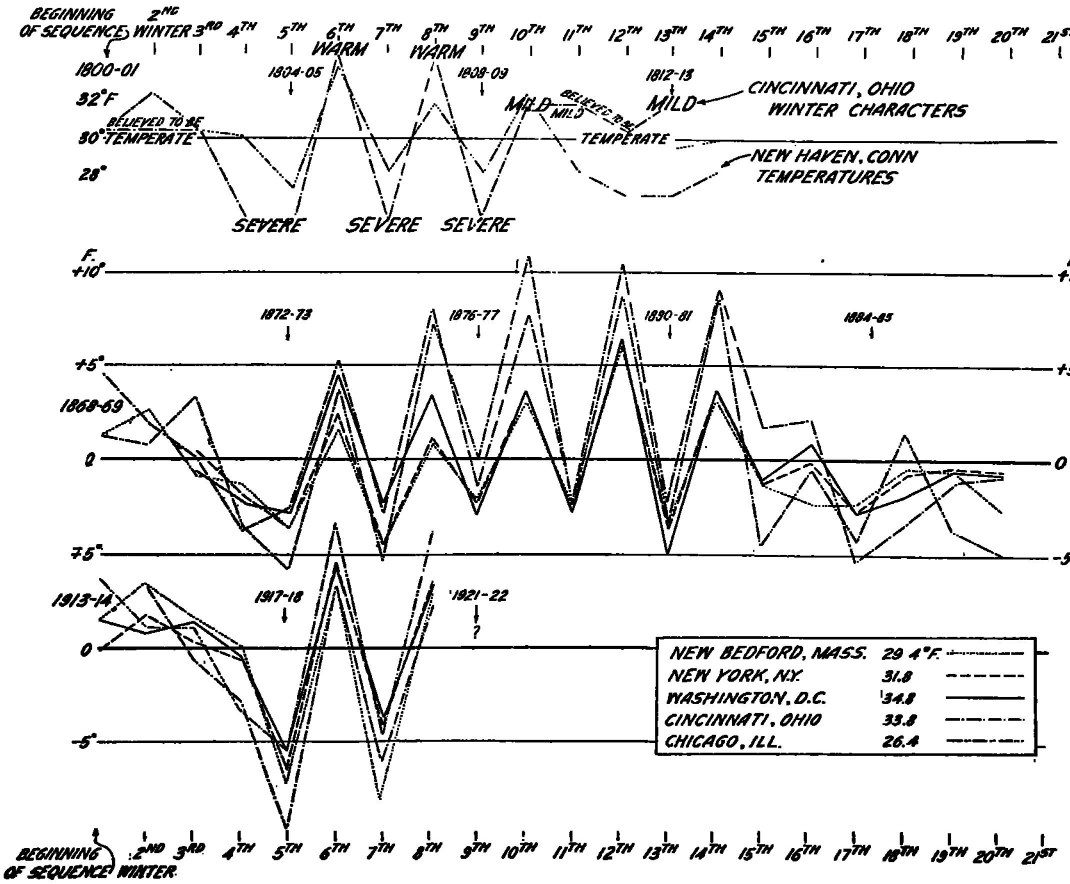

FIG. 1.—Three series of alternating winters in the northeastern United States since 1780. (NOTE.—The temperature departures for the winters 1868-1888 and 1913-1921 are those from the average of the 50 winters [(December+January+February)/3], 1870-1920.)

The alternations in the past 50 years were so striking that there seemed to be grounds for reasonably accurate forecasts of coming winters by means of these dot charts with their lines of best fit. Fortunately, there were records for 50 or more winters before 1870, which could be used as a test. It was disconcerting to find that the indications of these "forecasting" lines would have been no better than forecasts of "normal" for this earlier period. Practically all other like discoveries of alleged periodicities and correllations meet such a fate when critically tested.

On taking long records—100 years or more—as a basis for statistical study of sequences of winters, what have we left of the encouraging indications afforded by the last 50 years? The number of alternations, the sequence of appreciable alternations, and the sequence after the individual cold or warm winter (i. e., one of

winters, and then 45 years later produce another sequence of 8 winters almost exactly like that at the start of the long series of alternations. (See fig. 1.)

HOW LONG WILL THE CURRENT SERIES OF ALTERNATING WINTERS PERSIST?

Something about what to expect during the next few winters may be gained from a study of the weather maps of the Northern Hemisphere for the seventies and early eighties in comparison with those of the past five years and the present.[13] The New Bedford (1812–1920), New Haven (1780–1920), and Baltimore (1817–1920) records were examined for other periods having a sequence like those of 1868–1876 and 1913–1921, and but one was found, 1800–1808 (fig. 1). In a qualitative record of

[13] For other suggestions as to desirable lines of investigation, cf. references in footnote 9.

winters at Cincinnati, Ohio, 1788–1813, and 1817–1835 (when reliable instrumental records began), kindly compiled for me by Mr. W. C. Devereaux, the period of winters from 1800–1808 is similar to the New Haven record. (See fig. 1.) Figure 1 shows also the sequence of temperature (relative to average of last 50 years) from 1868 or 1870 to 1888 and from 1913 to 1921 at New Bedford, Mass., New York, N. Y., Washington, D. C., Cincinnati, Ohio, and Chicago, Ill. It will be noted that the sequence of the few winters preceding the beginning of the strong alternations was essentially the same in the series of 45 years ago and 113 years ago as that now in progress, and that the swings up and down are of the same order in the three periods. It seems not unreasonable to expect that the winter of 1921–22 will be a cold one and possibly that that of 1922–23 will be a warm one. Before we should dignify such expectations with the term "forecast," however, the characteristics of the weather in the early eighties, and, if possible, in the first decade of last century, should be compared closely with those of the present time, to enable us to recognize whether or not our present weather has characteristics of the years immediately preceding the break-up of the earlier periods of alternating winters.

Perhaps by finding the common factors of the general weather of North America and of the North Atlantic in the periods 1870–1876 and 1915–1921 we can get a preliminary understanding of why the winters alternate, and by studying the general weather of 1876–1883 what indications in the near future may be recognized as presaging the end of our current period of alternations.

Even if we can not say for winter after winter what the character is likely to be, we can say that immediately after a cold winter the chances are two to one or better in favor of a mild or warm one, and that a period of alternating cold and warm winters which is general over a large part of the eastern United States may continue for several winters, as cold-warm-cold, etc.

CONCLUSION.

Our winter temperature data show that in the sequence of winters are evidences of some control, and therefore that studies of the positions of grand centers of action of the atmosphere and their changes from winter to winter are well worth undertaking if we would have successful forecasts of the character of winters.

DISCUSSION.

By H. W. CLOUGH.

The paper of Dr. Brooks is essentially a contribution to the question of the existence of an approximate two-year period in weather. Such a period has been claimed by other investigators, notably Clayton [1] and Helland-Hansen & Nansen.[2] Clayton investigated a 25-month period which he found to persist with remarkable regularity during the seventies and eighties of the last century, but later on the periodicity disappeared.

Obviously it is important to determine to what extent these alternations differ in amount from what would be expected if there were no relationship between one winter and the following one. Besson has shown that in a series of N numbers there are $\frac{5}{12}$ (N–3) single rises and falls, or about 41 for every 100 numbers. This is the total number of single rises and falls. It is necessary in addition to determine the relative frequency of groups of successive alternations from 1 to 10. The formula deduced by the writer giving the probability of a series of n successive rises and falls in a series of unrelated numbers is approximately $\left(\frac{5}{12}\right)\left(\frac{3}{8}\right)^2\left(\frac{5}{8}\right)^{n-1}$. Thus the probability of a series of 10 successive rises and falls is about 0.085 for every 100 numbers and the total number of groups of five or more successive rises and falls is about 1.5 for each 100 numbers.

Applying Besson's tests to some of the series of winter temperatures compiled by Dr. Brooks, the results are shown in the following table:

Stations.	Number of years record.	Number of crests and hollows.	Per cent.	Single rises and falls.	Theoretical number.
Chicago	90	62	69	45	37
Cincinnati	85	57	67	40	34
Baltimore	103	70	68	45	42
New Bedford	107	68	64	43	43

It will be seen that the number of crests and hollows averages close to the theoretical 67 per cent for each 100 numbers. The number of single rises and falls is somewhat greater than the theoretical number for Chicago and Cincinnati and about the same for the longer series at New Bedford and Baltimore. The excessively large number of alternations in the seventies and eighties probably accounts for the excess in the number of single rises and falls. This is a unique series of 12 alternations and the chances are for one such occurrence in about 3,000 years if there were no relation between successive winters. This sequence, however, is so unique that it may be doubted whether it would occur again in 500 years or more. There is nothing even remotely paralleling it during the 140 years since observations are available in the United States. It is hard to escape the conclusion that this series indicates some sort of systematic relation between the successive winters, but, on the other hand, it may be equally true that the particular grouping of events combining to produce this series might not again occur in centuries.

There have been other groups of five or more successive alternations at single stations during the past 140 years. At Chicago there were two such groups of five or more single rises and falls; at Cincinnati, 3; at New Bedford, 2; at Baltimore, 2. The only noteworthy series common to two or more stations was one from 1890 to 1899, comprising seven to eight successive alternations shown at New Bedford, Baltimore, and Cincinnati. Some of the changes were, however, less than 2°, and changes from warmer to colder or colder to warmer, instead of changing from one side of the normal to the other side. The series shown on the diagram (p. 72) in Dr. Brooks's paper, from 1804 to 1810 at Cincinnati and New Haven, contains five alternations.

There are therefore, two, or at most three, series of five or more alternations during the past 140 years, covering any extensive area. The theoretical number, as stated above, is about 2. There is little, therefore, in this showing to support the theory of a systematic tendency to alternations of winter temperatures. The observed deviations from the theoretical number for a series of

[1] Clayton, H. H., A lately discovered meteorological cycle. *Amer. Metl. Jour.*, vol. 1 1885, pp. 130, 538.
[2] Helland-Hansen & Nansen, Temperature variations in the North Atlantic Ocean and the atmosphere. Smithsonian Institution. Misc. Coll., vol. 70, No. 4, 1920, p. 262.